# 7 RANGE DETERMINATION

## 7.1 Introduction

When a firearm is fired, gunshot residues in the following forms are discharged from the firearm:

- Burnt gunpowder particles
- Partially burnt gunpowder particles
- Un-burnt gunpowder particles
- Vaporous lead
- Particulate metals
- Shot pellet patterns

Muzzle-to-target distance determination is based on gunshot residue examinations and/or shot patterning examinations. These gunshot residues along with the morphology of the bullet hole or the size of the pellet pattern can effectively be used in determining the possible muzzle-to-target distance.

Valid conclusions in muzzle-to-target distance examinations are rooted in the reproduction of physical parameters related to the incident.

Elements needed to perform these examinations:

- Firearm
- Ammunition involved and components identified back to firearm
- Questioned pattern

It should be noted that if multiple chemical examinations are going to be performed on an item they must follow a specific order:

- First - Modified Griess (DAT or RAT)
- Second - Dithiooxamide
- Third - Sodium Rhodizonate (DAT or BTT)

The Modified Griess - Direct Application Technique (DAT) is used independently and/or in conjunction with other tests in range determinations. The Modified Griess - DAT test utilizes a chemical color reaction to help distinguish obscure or faint gunpowder patterns. This test detects nitrites, a product of the incomplete burning of gunpowder, by reacting with Acetic Acid to form nitrous acid. This nitrous acid combines with Alpha-Naphthol to produce an orange-red color reaction.

The Modified Griess - Reverse Application Technique (RAT) is used independently and/or in conjunction with other tests in range determinations. The Modified Griess - RAT test utilizes a chemical color reaction to help distinguish obscure or faint gunpowder patterns. This test detects nitrites, a product of the incomplete burning of gunpowder, by reacting with Acetic Acid to form nitrous acid. This acid combines with Alpha-Naphthol and produces an orange-red color reaction.

The Dithiooxamide (DTO) test is used independently and/or in conjunction with other tests in range determination. The DTO test utilizes a chemical color reaction to indicate the presence of copper. The DTO test reacts with copper to produce a dark greenish-gray to nearly black color reaction. It should be noted that the DTO test will also react with cobalt, leaving an amber-color reaction and nickel, leaving a violet-color reaction. This test can be effectively used in determining the physical characteristics of bullet holes including the determination of entrance vs. exit holes. Fired bullets passing through clothing and/or other objects, often leave traces of copper or nickel around the bullet hole. This copper or nickel transfer comes from the surfaces of a bullet containing copper or nickel, and/or the barrel of the firearm. This copper or nickel transfer can be in the form of minute particles, a fine coating of powder particles, or a fine cloud of

vaporized copper or nickel. At times this copper or nickel transfer is an obvious ring or wipe around the hole, but is more often invisible.

The Sodium Rhodizonate - Direct Application Technique (DAT) is used independently and/or in conjunction with other tests in range determinations. The Sodium Rhodizonate - (DAT) utilizes a chemical color reaction that is specific for lead and can effectively be used in determining the physical characteristics of bullet holes including the determination of entrance vs. exit holes. Fired bullets passing through clothing and/or other objects often leave traces of lead around the bullet hole. This lead transfer comes from the surfaces of the bullet, the barrel and/or the primer residue. This lead transfer can be in the form of minute particles, a fine coating of powder particles, or a fine cloud of vaporized lead. At times this lead transfer is an obvious ring or wipe around the hole but is more often invisible.

The Sodium Rhodizonate - Bashinsky Transfer Technique (BTT) is used independently and/or in conjunction with other tests in range determinations. The Sodium Rhodizonate - (BTT) utilizes a chemical color reaction that is specific for lead and can be effectively used in determining the physical characteristics of bullet holes including the determination of entrance vs. exit holes. Fired bullets passing through clothing and/or other objects often leave traces of lead around the bullet hole. This lead transfer comes from the surfaces of the bullet, the barrel and/or the primer residue. This lead transfer can be in the form of minute particles, a fine coating of powder particles, or a fine cloud of vaporized lead. At times this lead transfer is an obvious ring or wipe around the hole but is more often invisible.

**7.2 Safety Considerations**

Examination performed in the Firearm and Toolmark Section is inherently hazardous. These procedures involve hazardous chemical, firearms, ammunition, and power tools. All hazardous procedures must be performed in compliance with the DFS Safety Manual.

**7.3 Preparation**

**NOTE: ALWAYS ADD ACID TO WATER. NEVER ADD WATER TO ACID.**

7.3.1 Sodium Rhodizonate Solution

- The Sodium Rhodizonate solution is prepared fresh for each usage
- Prepare a saturated Sodium Rhodizonate solution by adding Sodium Rhodizonate to distilled water until the solution is a dark orange color

7.3.2 Hydrochloric Acid Solution

- Prepare a 5% Hydrochloric Acid solution by adding 5 milliliters of concentrated Hydrochloric Acid to 95 milliliters of distilled water
- Store solution in an appropriate, sealed container that is marked with the date and initials of the preparer
- Record in the Firearms Record Book

7.3.3 Buffer Solution

- Dissolve 1.9 grams of Sodium Bitartrate and 1.5 grams of Tartaric Acid in 100 milliliters of distilled water
- Store solution in an appropriate, sealed container that is marked with the date and initials of the preparer
- Record in the Firearms Record Book

7.3.4 Acetic Acid Solution

- Prepare a 15% Acetic Acid solution by adding 150 milliliters of Glacial Acetic Acid to 850 milliliters of distilled water
- Store solutions in an appropriate, sealed container that is marked with the date and initials of the preparer
- Record in the Firearms Record Book

- Prepare a 5% Acetic Acid solution by adding 50 milliliters of Glacial Acetic Acid to 950 milliliters of distilled water, store in an appropriate sealed container that is marked with the date and initials of the preparer
- Record in the Firearms Record Book

7.3.5 Dithiooxamide (DTO) Solution

- The Dithiooxamide solution is prepared fresh for each usage
- Prepare a Dithiooxamide solution by dissolving 0.2 grams of DTO in 100 milliliters of ethanol

7.3.6 Ammonium Solution

- Prepare an ammonium hydroxide solution by combining 20 milliliters of ammonium hydroxide in 50 milliliters of distilled water
- Store solution in an appropriate, sealed container that is marked with the date and initials of the preparer
- Record in the Firearms Record Book

7.3.7 Sensitized Blank for Griess Test

- Add 0.75 grams of Sulfanilic Acid to 150 milliliters of distilled water and mix
- Add 0.42 grams of Alpha Naphthol to 150 milliliters of methanol and mix
- Once both the solutions in step 1 & 2 are prepared, mix them together in a clean photo tray
- Saturate pieces of filter paper or desensitized photo paper in this solution
- Once the now sensitized blanks are dry, store in an airtight plastic container
- Utilizing these proportions, mix the quantity desired
- Store solution in an appropriate, sealed container that is marked with the date and initials of the preparer
- Record in the Firearms Record Book

7.3.8 Nitrite Test Strips or Cotton Swabs

- Dissolve 0.6 grams of Sodium Nitrite in 100 milliliters of distilled water
- Saturate pieces of filter paper or cotton swabs in this mixture
- Dry strips or swabs, then store in an airtight plastic container that is marked with the date and initials of the preparer
- Record in the Firearms Record Book

**7.4 Instrumentation**

- Scale/balance
- Stereo microscope
- Ruler or tape measurer

**7.5 Minimum Analytical Standards and Controls**

7.5.1 Positive Control (Modified Griess – DAT and RAT)

An acceptable positive control for the Modified Griess Direct Application Technique – DAT or the Modified Griess Reverse Application Technique - RAT procedure consists of placing a test mark and utilizing a Nitrite test strip or swab moistened with 15% Acetic Acid Solution on one of the sensitized blanks being used. An immediate orange-red color should appear on the sensitized blank. This color shift of the sensitized blank indicates the presence of nitrites. Result is to be recorded in the examiner's case notes.

7.5.2 Negative Control (Modified Griess – DAT and RAT)

An acceptable negative control for the Modified Griess Direct Application Technique – DAT or the Modified Griess Reverse Application Technique - RAT procedure consists of no color appearing on the sensitized blank when a clean test strip or swab that is moistened with 15% Acetic Acid solution touches the sensitized blank. Result is to be recorded in the examiner's case notes.

7.5.3 Positive Control (DTO)

An acceptable positive control for the DTO test consists of placing a test mark, utilizing a piece of known copper or nickel, on the item to be tested. This test mark must be well away from any holes to be examined. The DTO test is to be performed on the test mark. A positive result will be a dark, greenish-gray color for the presence of copper, and a blue-violet color for the presence of nickel on the test mark. The area surrounding this test mark should also be subjected to the DTO test. This area should not produce a color change and serves as the negative control. The results are to be recorded in the examiner's case notes.

7.5.4 Alternative Positive Control (DTO)

An alternative positive control for the DTO test consists of utilizing cotton swabs dampened with the ammonia solution. One of the treated swabs is rubbed against a piece of known copper or nickel. This swab is then processed with the DTO solution to insure that the test is reacting properly. A positive result is a dark, greenish-gray color for the presence of copper, or a blue-violet color for the presence of nickel on the swab. The results are to be recorded in the examiner's case notes.

7.5.5 Negative Control (DTO)

Another treated swab is rubbed on the item to be tested. This must be well away from any holes examined. This swab is then processed with the DTO solution to insure that the item being tested will produce no color reaction and serves as a negative control. The results are to be recorded in the examiner's case notes.

7.5.6 Positive Control (Sodium Rhodizonate Test)

An acceptable positive control for the Sodium Rhodizonate test consists of placing a test mark, utilizing a piece of known lead, on the item to be tested. This test mark must be well away from any holes to be examined. A positive result will be a pink color reaction after the application of the Sodium Rhodizonate solution and the buffer solution. After the application of a 5% Hydrochloric Acid solution, the color should change to a violet or purple if there is a presence of lead on the test mark. The areas surrounding the test mark should be subjected to the Sodium Rhodizonate test. This area should not produce any color change and serves as the negative control. Results are to be recorded in the examiner's case notes.

7.5.7 Alternative Positive Control (Sodium Rhodizonate Test)

An alternative positive control for the Sodium Rhodizonate test consists of utilizing cotton swabs dampened with a 5% Hydrochloric Acid solution. One of the treated swabs is rubbed against a piece of known lead. A positive result will be a pink color reaction on the swab, once it has been processed with the Sodium Rhodizonate and Buffer solutions. After the application of a 5% Hydrochloric Acid solution, the pink color should change to a violet or purple if there is a presence of lead on the test swab. The other swab should be subjected to the Sodium Rhodizonate test. This area should not produce any color change and serves as the negative control. Results are to be recorded in the examiner's case notes.

7.5.8 Negative Control (Sodium Rhodizonate Test)

An acceptable negative control for the Sodium Rhodizonate test consists of utilizing the other treated swab that is rubbed on the item to be tested. This must be well away from the holes examined. This swab should have no

color reaction once it has been processed with both of the Sodium Rhodizonate and Buffer solutions. The results are to be recorded in the examiner's case notes.

**7.6 Procedure or Analysis**

The evidence will be marked in accordance with the Quality Manual. A systematic approach should be used for range determination using the visual, microscopic, and chemical methods, with recording of findings and observations in examiner's case notes.

7.6.1 Visual and Microscopic Examination

The visual and microscopic examination of an item for gunshot residue will include the examination and/or consideration of the following:

- Presence of soot and/or smoke (size of pattern)
- Presence of particulate metals (shavings of lead, copper, brass, etc.)
- Presence of partially burnt and/or un-burnt gunpowder (size of pattern)
- Presence of melted adhering gunpowder
- A hole in the item (size)
- Presence of a visible ring around the perimeter of holes
- Location of all holes, tears, missing buttons, etc.
- Presence of burning, singeing, or melting
- Presence of any possible masking effects
- Pattern of artifacts surrounding holes
- Pellet pattern size

7.6.1.1 Interpretation of Results – Visual and Microscopic Examination

- Indicative of or consistent with the discharge of a firearm

  Vaporous soot/smoke
  Particulate metals (shavings of lead, copper, brass, etc.)
  Unburned gunpowder (morphology)
  Melted adhering gunpowder

- Indicative of or consistent with the passage of a bullet

  Holes in the item
  Visible rings around the perimeters of holes
  Location of all holes, tears, missing buttons, etc.

- Indicative of or consistent with a contact shot

  Ripping or tearing
  Burning or singeing
  Melted fibers
  Heavy vaporous lead residues
  Location of all holes, tears, missing buttons, etc.

- Possible masking effects

  Dark background color

Blood staining
Intervening object

- If the above observations support the findings of a "contact shot" no comparison is necessary
- If the observations do not support a "contact shot" finding, a working hypothesis will be formed based on the above observations, to be utilized in the comparison procedure
- Record findings and observations in examiner's case notes

7.6.2 Modified Griess – Direct Application Technique (DAT)

A systematic approach should be used for the Modified Griess (DAT).

- Place the sensitized blank (photo paper - emulsion side down, or sensitized filter paper) over the area to be tested
- Soak or spray a piece of nitrite-free appropriate material with the acetic acid solution, and place this over the reverse side of the evidence. Spraying the reverse side of the evidence with 15% Acetic Acid Solution may also be considered
- Apply heat and pressure with an iron until the Acetic Acid Solution treated material is dry

7.6.2.1 Interpretation of Results – Modified Griess (DAT)

- Any orange-red indications on the sensitized paper are the results of the chemically specific test for the presence of nitrite residues
- Record findings and observations in examiner's case notes

7.6.3 Modified Griess – Reversed Application Technique (RAT)

A systematic approach should be used for the Modified Griess (RAT).

- Wipe or spray the side of the sensitized blank that will be in contact with the questioned area with the Acetic Acid solution
- Place the sensitized blank (photo paper - emulsion side down, or filter paper) over the area to be tested
- Place a piece of nitrite-free appropriate material over either the sensitized blank or evidence depending on what is being used for a blank
- Apply heat and pressure with an iron until the Acetic Acid solution treated paper is dry

7.6.3.1 Interpretation of Results – Reverse Modified Griess (RAT)

- Any orange-red indications on the paper are the results of the chemically specific test for the presence of nitrite residues
- Record findings and observations in examiner's case notes

7.6.4 Dithiooxamide Test (DTO)

- A systematic approach should be used for the DTO Test
- Place three drops of the ammonia solution on a piece of filter paper
- Place the moistened area of the ammonia-treated filter paper over the hole to be tested
- Place a second piece of filter paper over the first and apply moderate pressure for approximately 5 seconds
- Remove both pieces of filter paper
- Place 3 drops of the DTO solution to the tested area of the filter paper that was exposed to the hole

- Repeat this process for all holes to be tested
- Both sides of holes should be tested if there is a question of entrance vs. exit

7.6.4.1 Interpretation of Results – Dithiooxamide Test (DTO)

- A dark, greenish-gray color reaction, corresponding to the area tested, constitutes a positive reaction for the presence of copper
- A blue-violet color reaction, corresponding to the area tested, constitutes a positive reaction for the presence of nickel
- Record findings and observations in examiner's case notes

7.6.5 Sodium Rhodizonate – Direct Application Technique (DAT)

A systematic approach should be used for the Sodium Rhodizonate DAT.

- Spray the Sodium Rhodizonate Solution on to the questioned area
- Spray the tested area with the Buffer Solution, noting the color reaction
- Either:

  Spray the tested area or a portion of the area with the Hydrochloric Acid Solution, noting the color reaction, or

  With a cotton swab dampened with 5% Hydrochloric Acid Solution, touch selected areas of the item, noting the color reaction.

Both sides of holes should be tested if there is a question of entrance vs. exit.

Repeat this process on all holes or areas to be tested.

7.6.5.1 Interpretation of Results – Sodium Rhodizonate (DAT)

- A violet or purple colored ring, corresponding to the margin of the hole, or a violet or purple colored stain, corresponding to the area tested, constitutes a positive reaction for lead
- Record findings and observations in examiner's case notes

7.6.6 Sodium Rhodizonate – Bashinsky Transfer Technique (BTT)

A systematic approach should be used for the Sodium Rhodizonate BTT.

- Uniformly dampen a piece of filter paper with the Acetic Acid Solution
- Place the treated filter paper over the hole or area to be tested
- Place a second piece of filter paper over the first and apply moderate pressure or apply a hot iron for approximately five seconds
- Remove both pieces of filter paper and spray the Sodium Rhodizonate Solution on to the tested area of the filter paper
- Spray the tested area of the filter paper with the Buffer Solution
- Either:

  Spray the tested area or a portion of the paper with the Hydrochloric Acid solution, noting the color reaction, or

  With a cotton swab dampened with 5% Hydrochloric Acid solution, touch selected areas of the paper, noting the color reaction.

Repeat this process on all holes or areas to be tested.

Both sides of holes should be tested if there is a question of entrance vs. exit.

7.6.6.1 Interpretation of Results – Sodium Rhodizonate – Bashinsky Transfer Technique (BTT)

- A violet or purple colored ring, corresponding to the margin of the hole, or a violet or purple colored stain, corresponding to the area tested, constitutes a positive reaction for lead
- Record findings and observations in examiner's case notes

7.6.7 Alternative Test – Screening Tool for Possible Bullet Impact Sites

This is an alternative test useful at scenes as a screening tool for possible bullet impact sites (non specific for lead).

- Dampen Benchkote paper with a 5% Acetic Acid Solution
- Press and hold the Benchkote paper over the hole or area to be tested for one (1) minute
- Apply 1 to 2 drops of Sodium Rhodizonate Solution onto the tested area of the Benchkote paper

7.6.7.1 Interpretation of Results – Alternative Test

- A red-violet color similar to the shape of the hole or mark is indicative of the presence of lead
- Record findings and observations in examiner's case notes

7.6.8 Test Pattern Production

A systematic approach should be used in conjunction with a working hypothesis formed by observations based on previous testing to include visual, microscopic, and chemical tests to produce test patterns with the appropriate firearm and ammunition for the purpose of developing a range determination.

- It is essential that the suspect firearm and appropriate ammunition be utilized for these tests
- Usually, one testfire should be shot for each piece of target media
- Tests should be shot in increasing or decreasing range increments until a distance range is established, that reproduces the gunshot residue patterns on the suspect item
- The range would include both shorter and longer distances than what was determined to reproduce the patterns on the questioned item
- Process target material with same chemicals as were used on questioned item
- Compare test patterns with questioned item

7.6.8.1 Interpretation of Results – Test Pattern Production

By utilizing the suspect firearm and appropriate ammunition it may be possible to obtain a reproduction of gunshot residue pattern(s) and or shot pellet pattern present on a questioned item. Chemically uncontaminated material or a section of the question material can be used while producing test patterns at known distances with the submitted firearm and appropriate ammunition. The known test patterns are then processed using the same methods that were applied to the questioned material. Comparing the test patterns to the questioned pattern(s), a determination may be possible as to the approximate bracketed distance a particular firearm's muzzle was from the questioned item at the time of firing.

Test may be produced from submitted evidence ammunition or laboratory stock ammunition. Tests shall be marked in accordance with the Quality Manual. The test-fired components, test patterns produced, and results of gunpowder test conducted on submitted evidence, will be returned to the submitting agency in a sealed condition with the other submitted evidence.

Analysis of tests produced from ammunition submitted as evidence will be reported in the Certificate of Analysis as follows:

> [number ( )] of the item [ ] cartridges/shotshells were used for test firing purposes. The resultant ammunition components and test patterns are being returned with the evidence and should be maintained for possible future examinations.

Analysis of tests produced from laboratory stock ammunition will be reported in the Certificate of Analysis as follows:

> [number ( )] cartridges/shotshells from laboratory stock ammunition were used for test firing purposes. The resultant ammunition components and test patterns produced are being returned with the evidence and should be maintained for possible future examinations.

Analysis of tests produced from ammunition submitted as evidence and tests produced from laboratory stock ammunition will be reported in the Certificate of Analysis as follows:

> [number ( )] of the item [ ] cartridges/shotshells and [number ( )] cartridges/shotshells from laboratory stock ammunition were used for test firing purposes. The resultant ammunition components and test patterns produced are being returned with the evidence and should be maintained for possible future examinations.

Additional tests from stock laboratory ammunition can be made for reference or training purposes. These tests should not subsequently be used for any identification purposes.

7.6.9 Suggested Formats for Reporting Conclusions of Examinations

7.6.9.1 Contact Shot

> Examination of the item __ shirt revealed a hole in the upper left chest area. The area around this hole was examined microscopically and processed chemically for the presence of gunpowder and lead residue (gunshot residues). Residues and the physical characteristics were found, which is consistent with this area of the shirt having been in contact with the muzzle of a firearm at the time of firing.

7.6.9.2 Distant Shot

> The area around the hole in the upper right arm area of the item __ jacket was examined microscopically and processed chemically for the presence of gunpowder and lead residues (gunshot residues), and a pattern was found. Using the item __ revolver and ammunition like the item __ and item __ cartridge cases, test patterns were prepared at various muzzle-to-target distances. Patterns similar to the pattern on the upper right arm of the item __ jacket were produced at a distance of between approximately two (2) and three (3) feet.

7.6.9.3 Maximum Distance at Which Residues are Deposited

> The area around the hole in the lower left back of the item __ sweatshirt was examined microscopically and processed chemically for the presence of gunshot residues. No residues were found. Using the item __ firearm and the item __ cartridges, tests patterns were produced at various muzzle-to-target distances. No residues were found at a distance of approximately six (6) feet or greater.

7.6.9.4 Lead Wipe with No Firearm

> The area around the hole in the left front lower leg of the item __ blue jeans was examined

microscopically and processed chemically for the presence of gunpowder and lead residues (gunshot residues). Residues were found which are consistent with the passage of a bullet, which is indicative that this area of the jeans was greater than the maximum distance at which such residues were deposited from the muzzle of the firearm at the time of firing, assuming no intervening object was present.

7.6.9.5 No Residues Found

The area around the hole in the left shoulder of the item __ shirt was examined microscopically and processed chemically for the presence of gunpowder and lead residues (gunshot residues) and no residues were found.

7.6.9.6 Shot Pellets

The chest area of the item ___ t-shirt was examined and a shot pattern was found. Using the item __ shotgun and ammunition like the item __ shotshell cases, patterns similar to that on the chest area of the item __ t-shirt were produced at a distance of between approximately nine (9) and eighteen (18) feet.

**7.7 Appropriate Appendices**

Appendix - Calibration Standards

Appendix – Work Sheets

**7.8 References**

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